# Benefits Analysis of Air Pollution Policies and Regulations

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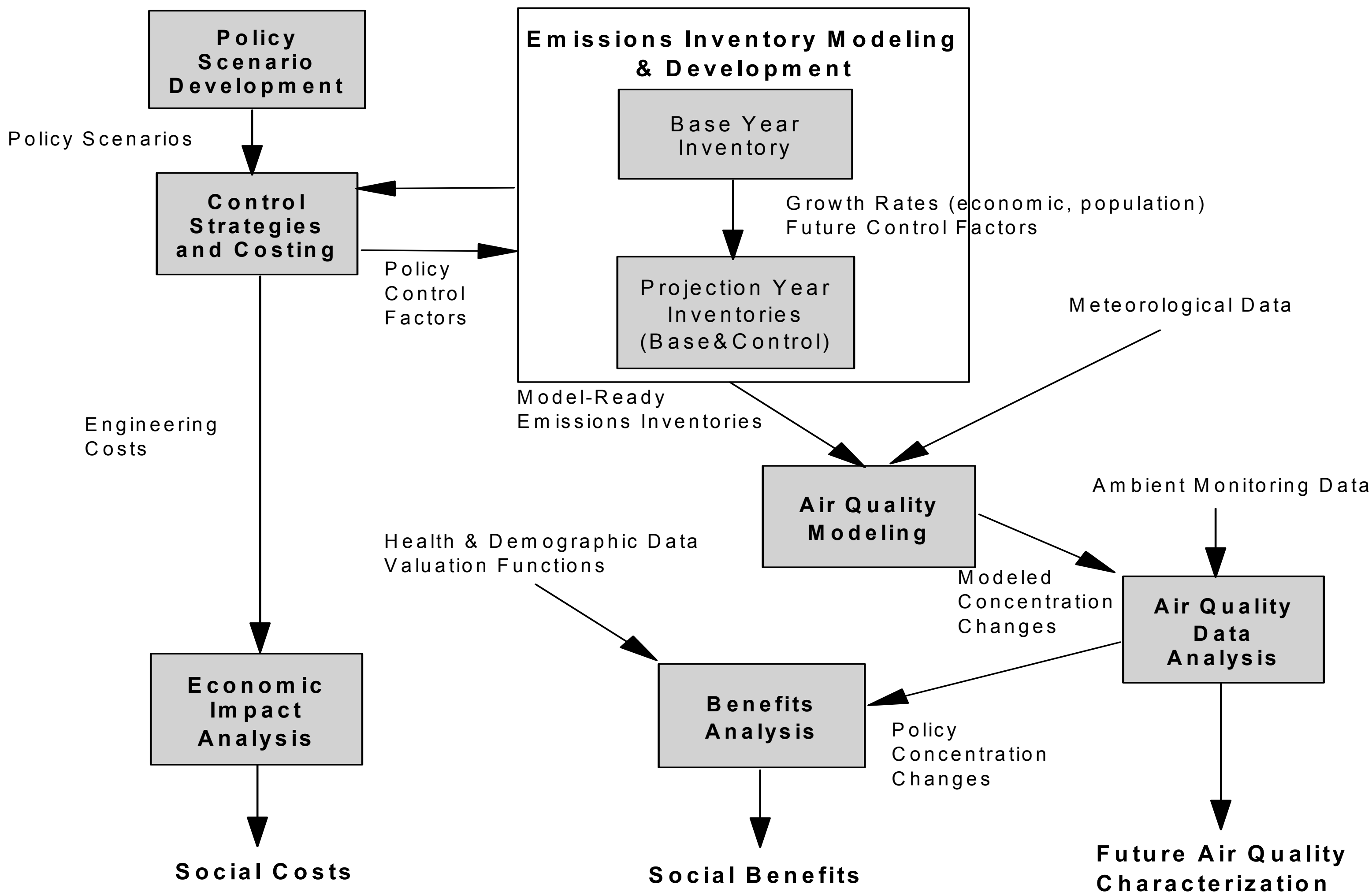
# Context

- Air emissions impacts of renewable energy are considered one of the major benefits of the technologies
- Methods and results from benefits analysis of air pollution policies and regulations may help energy modelers to quantify these effects

This presentation:

- Addresses analytic approaches for assessing benefits of air pollution policies and regulations
- Identifies major issues and uncertainties
- Introduces an EPA tool for benefits analysis
- Offers some results from sample analyses

Other presentations in this session address how energy modelers might use these methods and results


Policy Scenario Development
Policy Scenarios
Control Strategies and Costing
Policy Control Factors
Emissions Inventory Modeling & Development
Base Year Inventory
Growth Rates (economic, population)
Future Control Factors
Projection Year Inventories (Base&Control)
Meteorological Data
Model-Ready Emissions Inventories
Engineering Costs
Air Quality Modeling
Ambient Monitoring Data
Health & Demographic Data
Valuation Functions
Modeled Concentration Changes
Air Quality Data Analysis
Economic Impact Analysis
Benefits Analysis
Policy Concentration Changes
Social Costs
Social Benefits
Future Air Quality Characterization

# Elements of a Benefits Analysis

Establish Baseline Conditions (Emissions, Air Quality, Health, Environment)

Estimate Expected Reductions in Pollutant Emissions

Model Changes in Ambient Concentrations of Ozone and PM or Other Pollutants

Estimate Expected Changes in Human Health and Environmental Outcomes (Health and Environmental Impact Analysis)

Estimate Monetary Value of Health and Environmental Impacts (Benefits Analysis)

# How does EPA choose health outcomes to include in a benefits analysis?

- Advice from the EPA Science Advisory Board
- Consistency with particulate matter (PM) and ozone Criteria Documents and Staff Papers
- Well established concentration-response functions available from the peer-reviewed epidemiological literature
- No double-counting of benefits
- Focus on public health impacts rather than physiological responses

# What health effects do we quantify?

| | PM | Ozone |
|---|---|---|
| **Current** | | |
| Mortality | ✓ | (✓) |
| Chronic bronchitis | ✓ | |
| Nonfatal heart attacks | ✓ | |
| Hospital admissions | ✓ | ✓ |
| Asthma ER visits | ✓ | ✓ |
| Acute respiratory symptoms | ✓ | ✓ |
| Asthma attacks | ✓ | ✓ |
| Work loss days | ✓ | |
| Worker productivity | | ✓ |
| School absence rates | | ✓ |

# Emerging Public Health Impacts

- Infant mortality/low birth weight
- Decreased lung development
- Cancer
- Doctor visits
- New incidence of asthma

- Not quantified due to
  - Lack of appropriate baseline incidence rates
  - Not enough weight of evidence
  - Not easily monetized or characterized in terms of public health significance

# So what are the key pieces?

- Incidence rates
- Affected populations (prevalence)
- Estimated pollutant effect coefficients (concentration-response or C-R functions)
- Modeled changes in ambient air pollution

# Premature Mortality Example

$$\Delta Mortality = -\left[y_0 \cdot (e^{-\beta \cdot \Delta PM_{2.5}} - 1)\right] \cdot pop,$$

Key elements:

$y_0$ = county-level all-cause annual death rate per person ages 30 and older

$\beta$ = the pollution effect coefficient (obtained from epidemiological literature) = 0.0046

$\Delta PM_{2.5}$ = the modeled change in annual mean $PM_{2.5}$ concentration

pop = total population, 30 and older

# Key Sources of Uncertainty

- Projection of inputs and impacts across time and space
- Uncertainty regarding interpretation of observed data, i.e. potential thresholds in concentration-response functions
- Use of modeled changes in ambient concentrations of PM and ozone
- Use of valuation estimates based on similar but not identical health risks

# How does EPA currently handle uncertainty?

- Use Monte Carlo methods to characterize uncertainty around health impacts and valuation estimates
- For studies that can be pooled, estimate confidence intervals on quantified health effects accounting for within-study and between-study variability
- When pooling is not appropriate, present alternative estimates to show the impact of assuming different C-R functions or endpoint definitions
- Use sensitivity analyses to show the impact of thresholds and lag structures on mortality-related benefits

# Key issues of contention in recent analyses

- Thresholds in PM health effects *(SAB and NAS advice is to assume no threshold)*
- Length of lag between reductions in ambient PM and reductions in incidence of premature mortality *(SAB advice is to assume a 5-year distributed lag, NAS says to reconsider)*
- Lack of direct biological mechanism for observed epidemiological evidence of PM mortality *(SAB and NAS advice is to assume causality for purposes of benefits analysis)*
- Role of specific causal agents, i.e. sulfates or nitrates, within the complex mixture of PM have not been identified *(SAB and NAS advice is to treat all PM components equally but consider in uncertainty analysis)*
- Treatment of potential ozone mortality impacts *(SAB advice is pending)*
- Treatment of potential impacts of air pollution on prevalence of asthma *(SAB advice is to exclude in analysis)*
- Estimation of asthma related respiratory symptoms (*SAB advice is to include effects on asthmatic children*)
- Valuation of reductions in risk of premature mortality *(SAB advice is to use $6.3 million per statistical life saved)*
- Use of life years vs. lives saved *(SAB advice is to use lives saved for benefit-cost analysis, life years may be useful for cost-effectiveness analysis)*

# Key elements of the benefits analysis that have not received sufficient input from the scientific community

- Health baseline definition,
- Apportionment of risk changes among multiple pollutants,
- Statistical model selection, i.e., threshold or linear
- Definition of the affected population(s),
- Quantification of the distribution of risk among subpopulations, and
- Appropriate methods for quantifying uncertainty in the health benefit estimates.

# “Built-in” assumptions

- C-R function is non-threshold and can be extrapolated down to background concentrations *(follows SAB advice, supported by current literature)*
- C-R function can be transferred from study location to all locations in the U.S. *(we use estimates pooled across locations where available)*
- In general, C-R function only applies to population examined in study, however, SAB has suggested extending asthma attacks to children aged 6 to 18
- C-R function is constant over time and environmental conditions

# How do we value improvements in public health?

- Cost of illness (COI)
  - Hospital admissions
  - Work loss days
- Willingness to Pay
  - Premature death
  - Chronic bronchitis
  - Respiratory symptoms
- Quality adjusted life years (QALY) – measured in terms of "healthy" life year equivalents rather than dollars

# Cost of illness

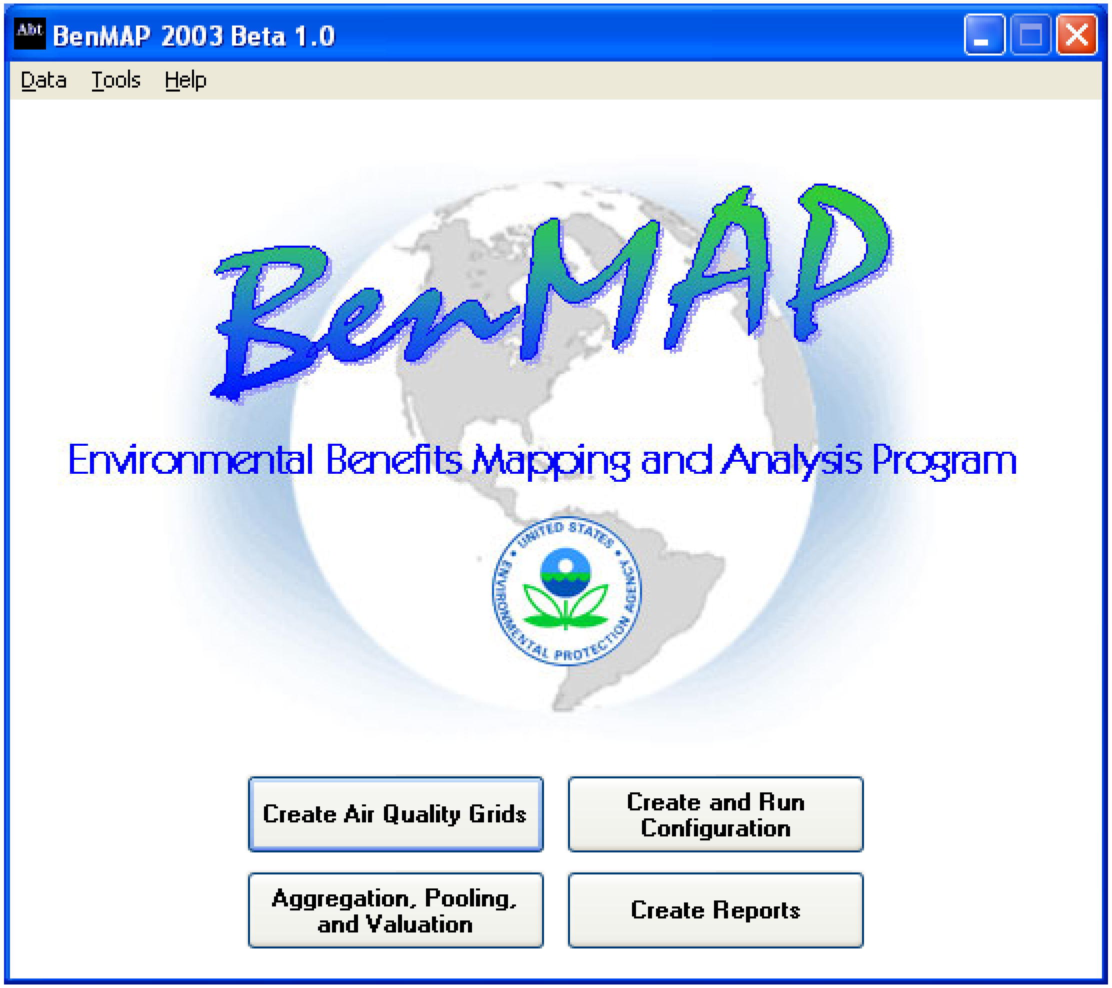
- Captures the direct dollar savings to society of reducing a health effect
- Ignores the value to individuals of reduced pain and suffering
- Generally a lower bound when no WTP estimates are available

# Willingness to Pay

- Measures the complete value of avoiding a health outcome
- Relies on either revealed or stated preferences for risk reductions
  - Revealed preferences from labor market studies provide values for fatal risk reductions
  - Stated preferences from “contingent valuation” studies provide values for chronic illnesses and acute respiratory effects
- Generally more uncertain than COI

# Current mean values for health effects (2000 $)

| | |
|---|---|
| • Premature death: | $6.3 million (WTP) |
| • Chronic bronchitis: | $340,000 (WTP) |
| • Heart attacks | $67,000-$141,000 (COI) |
| • Hospital admissions: | $7,000 - $18,000 (COI) |
| • ER visits: | $300 (COI) |
| • Acute bronchitis | $360 (WTP) |
| • Respiratory symptoms | $15 - $50 (WTP) |
| • Asthma attacks | $40 (WTP) |
| • Work loss days | $100 (COI) |
| • School loss days | $75 (COI) |


BenMAP 2003 Beta 1.0
Data
Tools
Help
BenMAP
Environmental Benefits Mapping and Analysis Program
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Create Air Quality Grids
Create and Run Configuration
Aggregation, Pooling, and Valuation
Create Reports

# Key Features of BenMAP

- Includes all of the key inputs to a benefits analysis
- The user only has to provide modeled data – or select monitor data for a "what if" style analysis
- BenMAP is an integrated GIS mapping, query, and statistics tool
- Outputs results (exposure, incidence, and valuation) in a variety of formats, including spreadsheets and shape files suitable for use with standard GIS packages such as ArcView

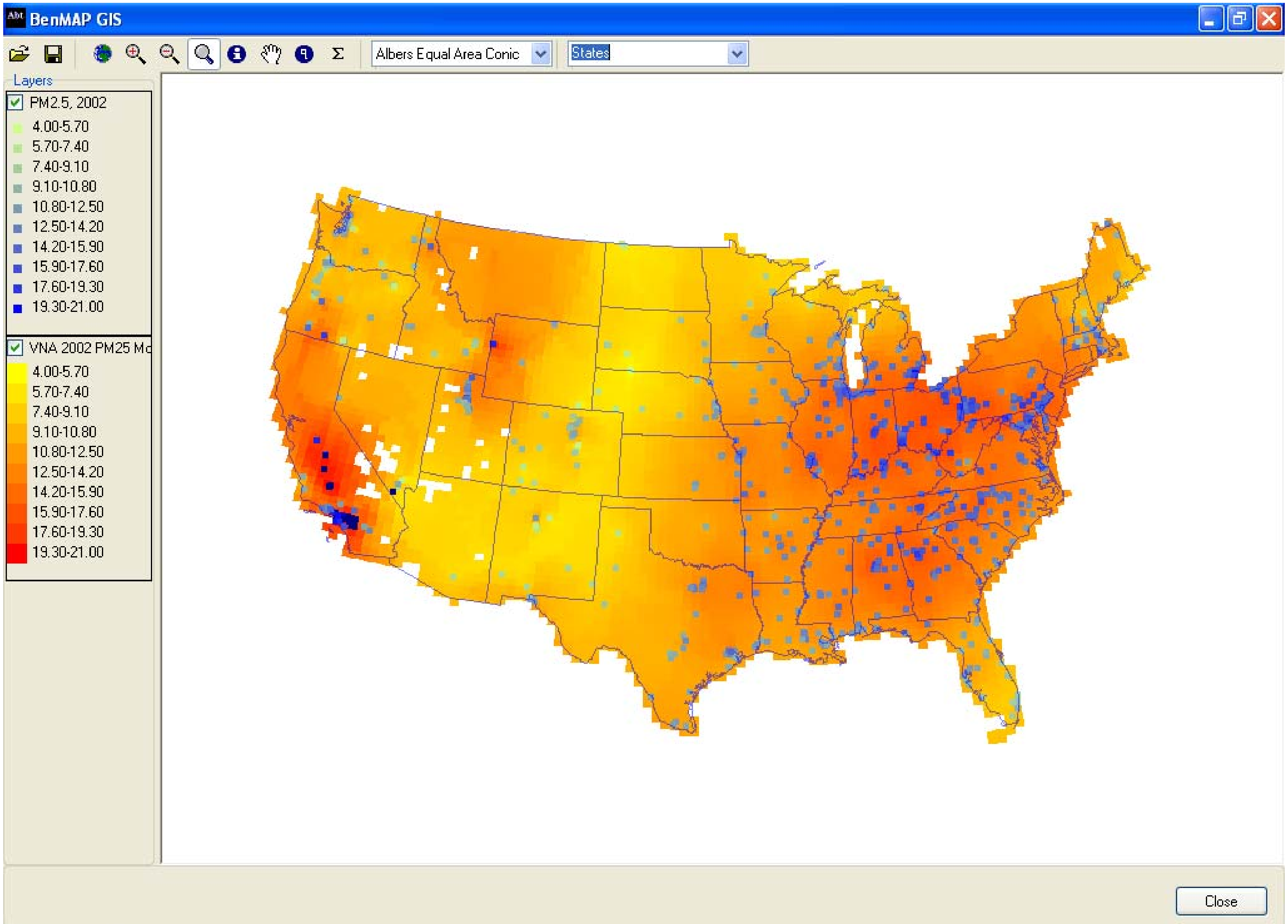
# Key Features of BenMAP

- BenMAP is relatively fast
  - Can produce a simple benefits analysis in minutes or a complex analysis within a work day
  - Can be run in batch mode to quickly produce analyses of multiple control scenarios
- BenMAP is cheap to run
  - BenMAP allows analysts to complete benefits analyses in-house, saving contract dollars
  - BenMAP can be modified to work with a number of air quality models, so that advances in modeling can be easily adopted in benefits modeling

# Air Quality Features

- Able to use a wide variety of air quality data, both monitored and modeled
- Preloaded with AIRS data for ozone, PM10, and PM2.5 for a number of recent years (1996-2002)
- Provides several options for creating population exposure maps
  - Direct use of monitor or model data
  - Use of model data with monitor data in a relative sense – allows for greater reliance on observational data in making future air quality predictions

# Example of Air Quality Input Map



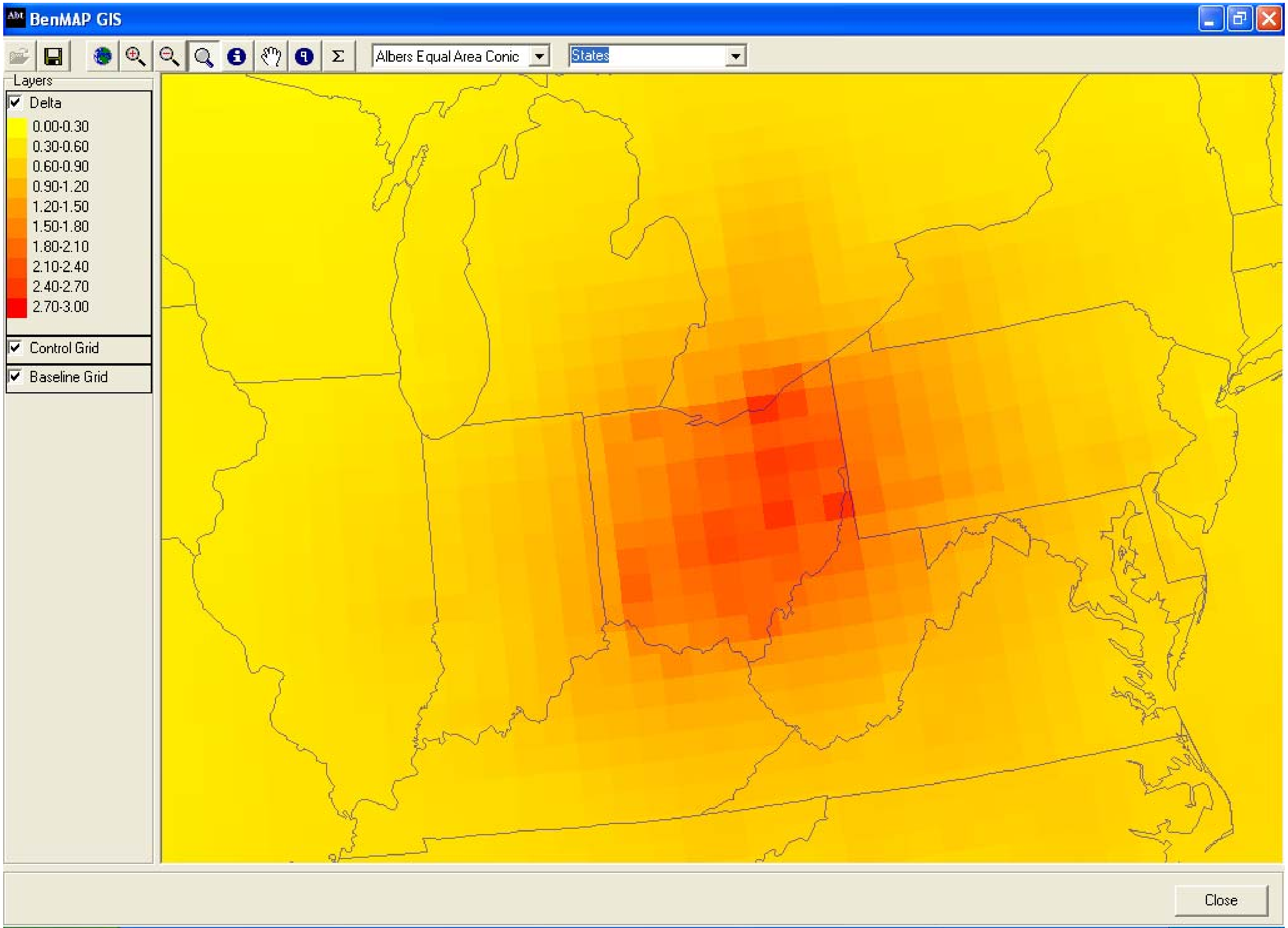
# Benefits Analysis Features

- Preloaded with hundreds of C-R functions and valuation functions, users can easily add more with the full featured equation editor
- Can aggregate results at the county, state, or national level
- Provides tools for integrated uncertainty analysis
  - Provides flexibility in pooling and summing incidence and valuation results
  - Estimates distributions of incidence and valuation results using Monte Carlo methods

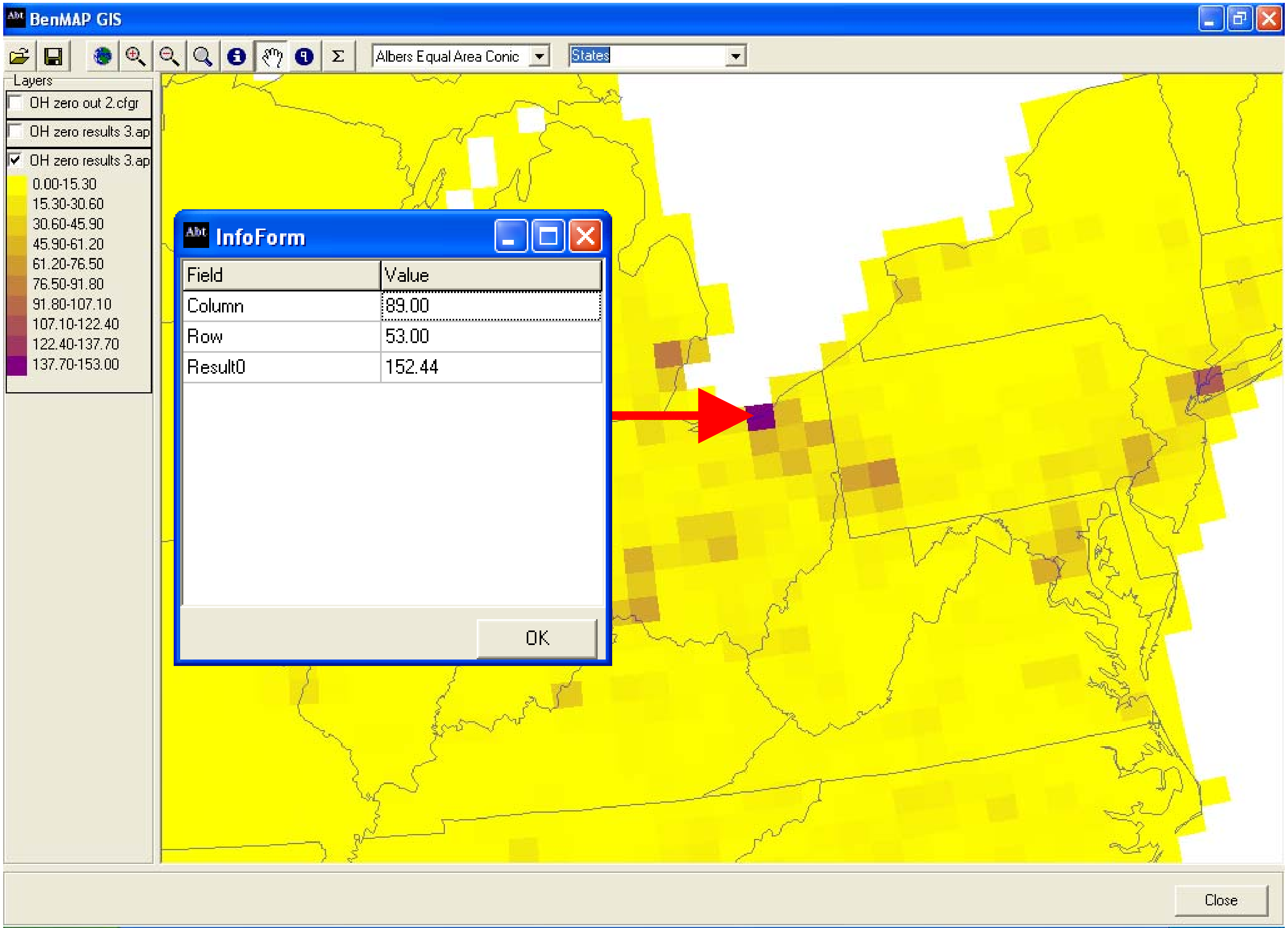
# Outputs

- You can export results to a number of formats, including spreadsheets or GIS shape files
- You can also view your results using the mapping tools available on the menu bar

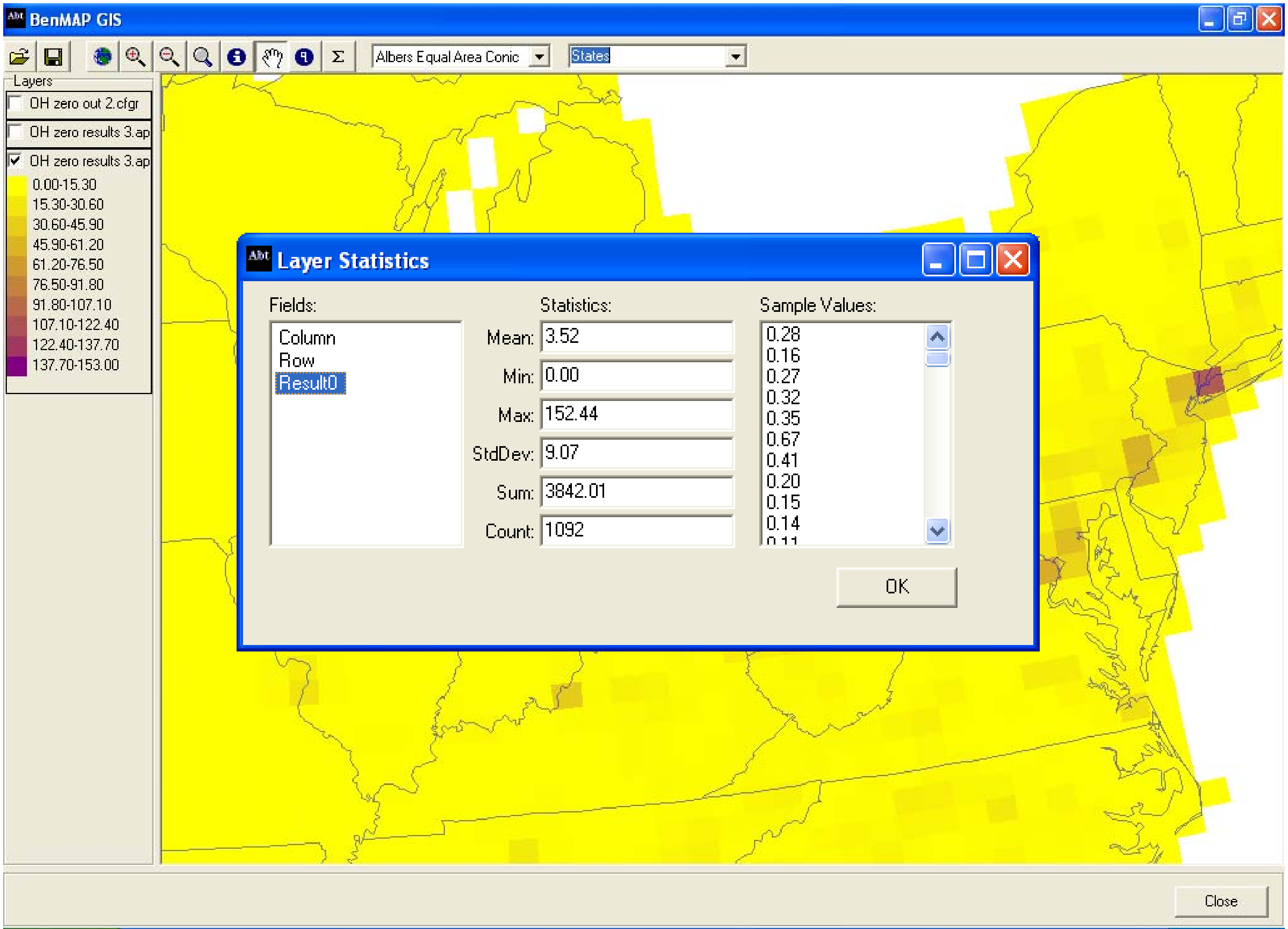
# Example of Mapped Change in Ambient Particulate Matter



# Example of Mapped Change in Mortality Incidence Results



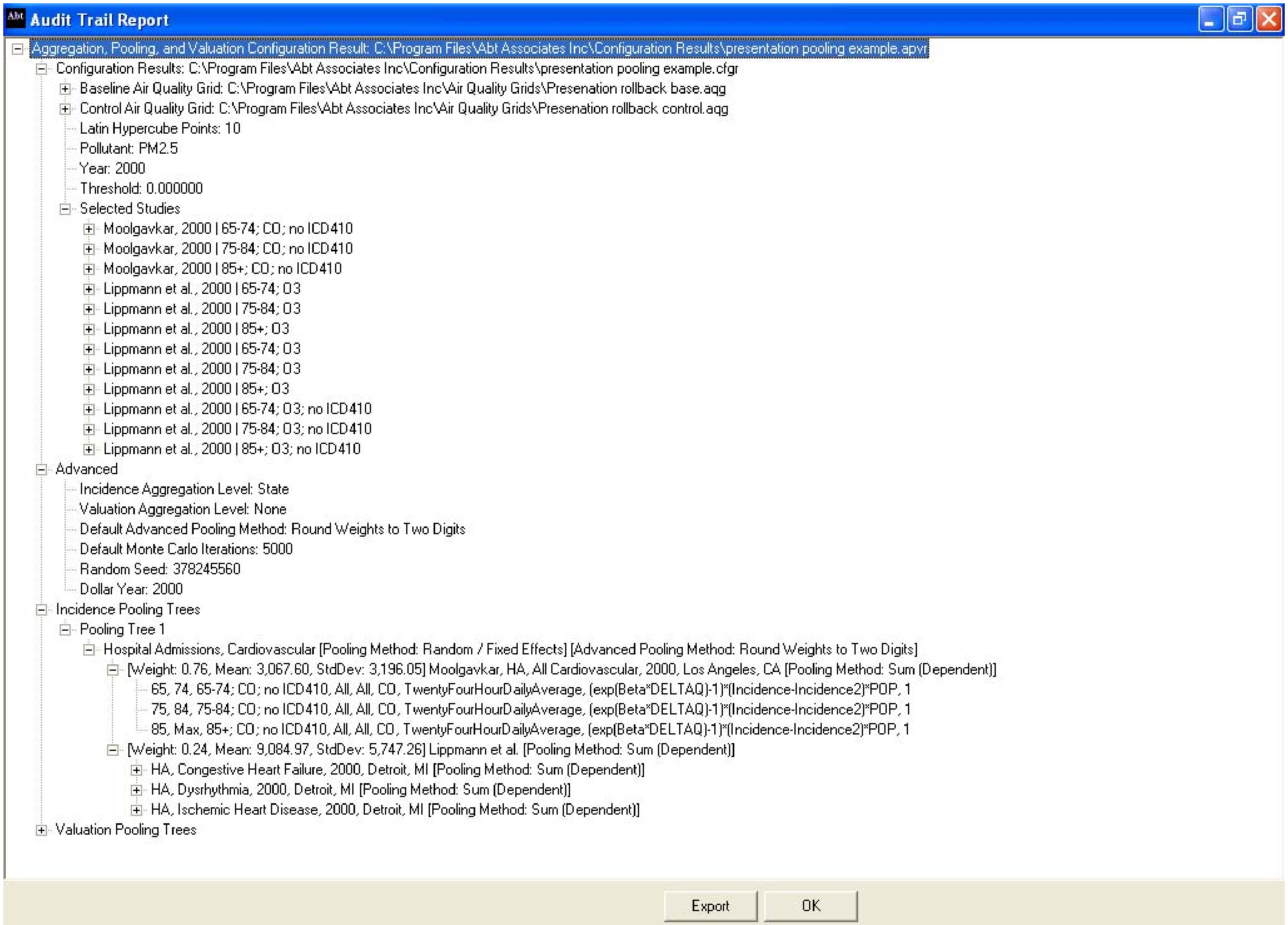
# Example of Mapped AQ and Mortality Incidence Results



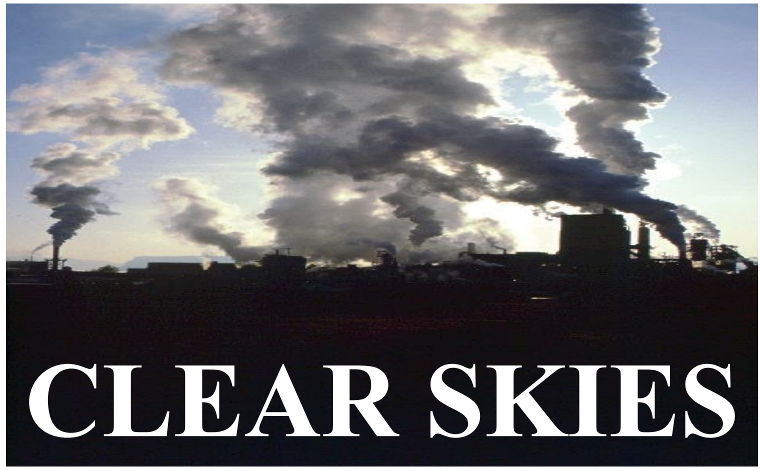
# Transparency

- BenMAP is ultimately intended for public use and public scrutiny
- We have included a detailed User's Guide with extensive appendices documenting model algorithms and data sources
- With each run, the user can generate an "audit trail" listing details of the run for QA and comparison with other analyses
- Consistent with Data Quality Guidelines, this "audit trail" can and should be shared with reviewers

# Audit Trail Example



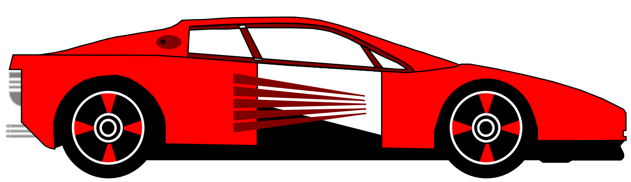
# Results of recent analyses




- Utility NOx and SO2 caps of 1.7 million and 3 million tons respectively
- 14,100 premature mortalities avoided
- 8,800 cases of chronic bronchitis avoided
- 30,000 hospital admissions avoided
- Millions of respiratory symptoms days avoided
- Millions of work loss days avoided
- Valued at $113 billion (relative to $6.3 billion in costs)

# Results of recent analyses (cont)

- Tier 2 and Heavy Duty Engine regulations
  - Reduces NOx emissions by over 5 million tons by 2030
  - 13,000 premature mortalities avoided
  - 7,800 cases of chronic bronchitis avoided
  - Millions of acute respiratory symptoms and work loss days avoided
  - Valued at over $100 billion



# Results of recent analyses (cont)

- Nonroad Diesel Engines
  - By 2030, reduces NOx emissions by over 800,000 tons and diesel PM by over 126,000 tons
  - 9,600 premature mortalities avoided
  - 5,700 cases of chronic bronchitis avoided
  - 16,000 nonfatal heart attacks avoided
  - Millions of acute respiratory symptoms and work loss days avoided
  - Valued at over $80 billion